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ABSTRACT

Three experiments were conducted with 51 college age beginning statistics students to assess the validity of six popular beliefs about factors related to statistics achievement. Mathematics background and ability, logical reasoning ability, attitude toward statistics, and anxiety were all found to have some relationship to statistics achievement. Differences between graduates and undergraduates, and men and women, were also explored. No significant differences were found between the groups on any single factor related to statistics achievement. There were, however, differences in how those factors combined to affect achievement for the different groups. It was concluded that no one variable explored here is singularly necessary for achievement in beginning statistics. (Author)

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The Validity of Six Beliefs About Factors Related to Statistics Achievement

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Abstract

Three experiments were conducted with college age beginning statistics students to assess the validity of six popular beliefs about factors related to statistics achievement. Mathematics background and ability, logical reasoning ability, attitude toward statistics, and anxiety were all found to have some relationship to statistics achievement. Differences between graduates and undergraduates, and men and women, were also explored. No significant differences were found between the groups on any single factor related to statistics achievement. There were, however, differences in how those factors combined to affect achievement for the different groups. It was concluded that no one variable explored here is singularly necessary for achievement in beginning statistics.

Factors Related to Statistics Achievement

The value of a background in statistics for educational researchers and practitioners can hardly be disputed, and yet many otherwise successful students find beginning statistics to be a difficult, even fear-inducing course. Due to the special nature of the course, many statistics instructors have formulated assumptions about the reasons for their students academic difficulties in statistics, often on the basis of little empirical evidence. While several studies have investigated the relationship between mathematics achievement and learner characteristics, this study will focus specifically on the relationship between selected learner characteristics and achievement in an introductory educational statistics course. Some of the factors popularly believed to influence statistics achievement have been incorporated into six commonly held beliefs:

1. Anxiety is debilitating to statistics achievement in the classroom.
2. Undergraduates and graduates should be taught separately, as they approach and react to statistics classes differently.
3. Previous mathematics achievement is important to successful completion of a course in statistics. You cannot do well in statistics if you do not do well in mathematics.

4. There are differences between men and women in terms of the factors related to statistics achievement.
5. Attitude about statistics influences achievement in statistics classes.
6. "Logical thinking ability" is important in statistics achievement.

Previous work in statistics achievement, though sparse in number of studies completed, has examined a wide variety of learner characteristics including anxiety, mathematics achievement, mathematics experience, attitude, and various demographic variables (e.g., age, year in school). For example, Feinberg and Halperin (1978) measured a sample of 278 introductory statistics students. The authors found both affective and cognitive variables, including state anxiety, experience in mathematics, attitude toward mathematics, and expectations about course performance were important predictors of course achievement. The finding that a variety of both cognitive and affective variables were important indicates that neither component should be isolated when attempting to predict performance or when developing remediation programs.

The rich variety of variables affecting statistics achievement indicate the potential for different variables to interact in producing the same results. This was, in fact, demonstrated in a study by Plake, Smith, and Kaplan (1982), who found that although

men and women achieved similar overall results on a mathematics test, the factors which predicted those results differed in both kind and magnitude between gender. Therefore, this study will examine the differential effects of group membership (male/female, undergraduate/graduate) in terms of the pattern of different variables which predict course achievement.

Several studies, (Bledsoe and Perkins, 1976; Feij,1976; Woelke and Leitner, 1980), have found mathematics achievement to be important in predicting introductory statistics achievement. Woelke and Leitner, however, found mathematics achievement to be important only in the lower level courses, indicating that perhaps only a moderate level of mathematics ability may be necessary. The lower level courses appear to have screened out those with deficient mathematics skills. For those beyond that minimal level, extra mathematics skill was not necessary. It is possible that it is not so much the computational skills which are necessary as it is the mathematically related logical reasoning skills which are, in part, built through experience in mathematics courses.

In this study, three experiments are discussed that attempt to replicate previous studies and to extend them to include an analysis of the six beliefs stated earlier. The first experiment examined anxiety, logical reasoning, and mathematics background, and how they may combine in patterns to predict statistics

achievement for undergraduate and graduate students. The second and third experiments were designed to follow up the initial results and to extend them to include measures of attitude, mathematics achievement, and to investigate differences between men and women in statistics achievement.

EXPERIMENT 1

Method

Subjects. Subjects consisted of 51 introductory statistics students in an educational psychology department at a large midwestern university. There were 20 undergraduate and 31 graduate students, 13 men and 38 women. The subjects were recruited on a volunteer basis from three separate classes, all of which contained both graduates and undergraduates.

Instruments. Anxiety was measured using both scales of the State-Trait Anxiety Inventory (Spielberger, Gorsuch, and Lushene, 1970). The State Scale is designed to measure the subjects' anxiety about a particular situation, while the Trait Scale is designed to measure the subjects' characteristic level of anxiety. Logical reasoning was assessed using the Test of Logical Thinking (TOLT) developed by Tobin and Capie (1981). The TOLT is a ten-item paper-and-pencil test designed to emulate a Piagetian interview. Mathematics background was determined by subjects' self-report of mathematics courses taken in high school and

college, and the number of years since taking a mathematics course.

Procedure. The State-Trait Anxiety Inventory (STAI), TOLT, and mathematics background inventory were administered at the beginning of the semester. Classroom examination scores were used to assess achievement in the course at the beginning (first examination) and end (final examination) of the semester. Examination scores for the three classes were equated by using T scores based on the results for each separate class.

Results

Means and standard deviations for each of the measures are reported in Table 1. Pearson correlation coefficients for the total group are reported in Table 2. TOLT, state anxiety (STA), and number of mathematics courses (NOF) were significantly correlated with performance on the first examination. The TOLT, and STA scales were significantly correlated with the final examination scores. Next, stepwise regression analyses were used to examine the combined effects of TOLT, STA, TRA, NOF, and YRS on statistics achievement for the total group. For the first examination, the parsimonious regression equation accounted for 31% of the variance for the total group. The variables, in order of entry, were STA and TOLT. For the final examination, TOLT and YRS combined to account for 27% of the variance for the total group.

Independent t-tests were used to determine whether the differences between groups on the final examination score were significant. No significamt differences were detected for either undergraduates and graduates ($t(44) = -1.44$, $p < .16$) or men and women ($t(44) = -1.15$, $p < .29$). Separate regression analyses for the graduates indicated that STA was the only significant predictor of the first examination score, accounting for 21% of the variance, $F(1,29) = 7.98$, $p < .01$. Trait anxiety and TOLT were significantly predictiive of the final examination score for graduates, accounting for 56% of the variance. For the undergraduates, only TOLT reached significance on the first examination, accounting for 35% of the variance, $F(1,18) = 9.89$, $p < .01$. No variable reached significance for the final examination. Summaries of the regression analyses for total group and graduate students are contained in Tables 3 through 5. No analyses were done for the different sexes due to the small number of men participating in the study.

Conclusions

These results indicate that formal reasoning ability is important in beginning statistics, as are previous experiences in mathematics classes. It is interesting to observe, however, that State anxiety was only a significant predictor on the first examination. This may, in fact, have been a phenomenon of the type of measure used and the manner in which it was used, since

State anxiety was gathered at the beginning of the course and it is possible that anxiety levels changed in magnitude or variability by the end of the course. It is also unclear whether the anxiety is due to the course topic in general, or to the specific testing situation.

Further, differences were indicated in the predictors of undergraduate and graduate students' performance in statistics. Anxiety appears to be an important factor for graduate students, while not significantly affecting the performance of undergraduates. These results must be interpreted cautiously due to the small sample size. Some possible contributing explanations for these differential effects, however, can be postulated.

The first possible explanation for the differential effects of anxiety on achievement may be due to the underlying source of the anxiety. If the source of the anxiety is indeed the testing situation, rather than the subject matter per se, then the graduate students are perhaps at a disadvantage. Graduate students in a lower level graduate course such as this have often been out of school for some time and are unused to traditional test taking situations. In addition, students are evaluated in most graduate courses by written papers and essay format examination questions, which is far different from the multiple choice question format used here. The undergraduate students in this study, on the other hand, were typically at the end of a

three- or four-year program of study, and have been given a variety of test formats on numerous occasions.

If the effects of anxiety are due, not to the testing situation, but the subject matter itself, the differential effects may be due to either the attitude of the student toward the subject matter, or the course background of the student. Graduate students are more likely to be completing the statistics course as a requirement for graduation, and are required to achieve at a higher level in order to be considered successful.

Based on these results, a second experiment was conducted to more closely explore the effects of mathematics ability, anxiety, and the differences in achievement between graduates and undergraduates.

EXPERIMENT 2

Experiment 2 focused primarily on the differences between graduates and undergraduates, and on the effects of anxiety across the semester. The experiment focused on three classroom situations. The first class consisted of both graduates and undergraduates, while the second and third classes were split on the first day into an all graduate class and an all undergraduate class. This afforded a unique opportunity to look at the effects of homogenous groupings on anxiety and attitude.

Method

Subjects. A total of 88 subjects participated in the study. Of the 88, 29 were men, 59 were women, 41 were graduate students and 47 were undergraduates. Subjects were recruited on a volunteer basis at the beginning of the semester.

Instruments. To measure anxiety, the STAI was again used, as well as the Mathematics Anxiety Rating Scale-Revised (MARS-R), an instrument designed to measure mathematics anxiety specific to statistics (Plake & Parker, 1982). In addition, two separate instruments were designed to measure mathematics ability (primarily algebra skills) (Plake, Ansorge, Parker, & Lowry, 1982) and attitude toward statistics (Wise, in press). To equate the different classroom tests used by the instructors, z scores were used as examination scores.

Procedure. The MARS-R, TRA, mathematics ability test (MATH), and the Attitudes Toward Statistics scale (ATS) were given at the beginning of the semester. The STA was given twice during the semester, one week prior to the first and final examinations.

Results

The means and standard deviations for Experiment 2 are presented in Table 6. Results indicate that MARS-R, the first administration of STA (STAI), MATH, and ATS were all significantly correlated with performance on the first examination. The second administration of STA (STA2) and MATH were significantly

correlated with both the final examination, and the average of the course examinations. Pearson correlation coefficients are presented in Table 7. MARS-R, TRA, STA1, and MATH were used in a stepwise regression analysis to compare their effects in predicting examination scores of the total group, men and women, and graduates and undergraduates.

MATH was the only significant predictor for the total group, men, and undergraduates, accounting for 10%, 34%, and 13% of the variance, respectively. No other variables were significant predictors of examination scores for any group.

A three-way ANOVA with class level (undergraduate/ graduate) and sex as between-subjects factors and time as a within-subjects factor investigated the change in State anxiety during the semester. No significant interactions or main effects were found. A two factor MANOVA, with sex and class level as the independent factors, was performed to assess significant differences in cumulative score, MATH, and ATS. The overall multivariate F test was not significant.

One-way ANOVA's were used to explore any differences in STA2 or ATS due to homogenous class groupings. No significant differences were found.

Conclusions

Mathematics ability is a significant predictor of success in statistics and appears to be more important for undergraduates or

men than for graduates or women. It is interesting to note that there were no significant differences between graduates and undergraduates, or between men and women in attitude, mathematics ability, or achievement. This supports the view that, while mathematics is important to achievement, it can apparently be compensated for by other abilities.

Anxiety did not appear to change in magnitude across the semester, yet anxiety measures taken at the beginning of the semester had little bearing on the actual achievement outcomes in the long run. Anxiety appeared to be more a function of the actual testing situation than of how anxious the student is at the beginning of the course.

No differences in performance appeared to occur when students were split into more homogenous groups along the line of class level. Having a more homogenous group did not reduce anxiety for either graduates or undergraduates, nor produce differential attitudes. This, together with the lack of differences found elsewhere would indicate that separating students into sections based on class level is neither beneficial nor damaging to either group.

EXPERIMENT 3

Experiment 3 was conducted in order to explore the change across semester of anxiety not specifically related to the test situation, and to test the stability of the regression results

from Experiment 2. In addition, the ATS was divided into two scales, attitude toward the field of statistics (FIELD) and attitude toward the statistics course (COURSE), in order to determine if there are differential effects for the two measures.

Method

Subjects. Subjects were 147 introductory statistics students from three sections of heterogeneously grouped graduate and undergraduate students. Of the 147, 83 were graduate students, 64 were undergraduates, 38 were men, and 109 were women. Subjects were recruited at the beginning of the semester on a volunteer basis.

Instruments. The MARS-R was again used to measure anxiety. A shortened version of the same mathematics test used in the previous experiment was used to measure mathematics ability (Parker, 1985). The ATS was again used to measure attitude, but this time two scales were identified to differentiate attitude toward the field of statistics and attitude toward the statistics course. Classroom test scores were again equated by using z scores.

Procedure. The mathematics ability test-short form (MATH-S), the ATS, and the MARS-R were given at the beginning of the course. The MARS-R was repeated approximately two-thirds of the way through the course. Its administration was timed to come between

tests to attempt to partial out test anxiety from anxiety about the field of statistics as much as possible.

Results

The means and standard deviations for Experiment 3 are presented in Table 8. The first and second administrations of the MARS-R, MATH-S, and attitude toward the course (COURSE), were all significantly related to course performance. Pearson correlation coefficients are presented in Table 9.

The first administration of MARS-R, FIELD, COURSE, and MATH-S were used in a stepwise regression analysis to inspect their sequential predictive effects for course performance using the total group, men and women, and undergraduates and graduates. The MATH-S scores proved to be the most potent predictor for the total group, $F(1,75) = 16.45$, $p < .0001$, accounting for 18% of the variance. This was also true for graduates ($F(1,45) = 6.59$, $p < .014$), undergraduates ($F(1,27) = 15.50$, $p < .0005$), and women ($F(1,59) = 15.67$, $p < .0002$). Variance accounted for is 13%, 36%, and 21% respectively. For men, FIELD was the most potent predictor, $F(1,14) = 4.84$, $p < .05$, accounting for 26% of the variance.

A three-way ANOVA with sex, class level, and time was performed with MARS-R as the dependent variable. A significant difference was found between the two administrations of the

MARS-R, $F(1,77) = 7.73$, $p < .007$. ANOVA results are reported in Table 10.

A two factor MANOVA, again using sex and class level as independent variables was used to assess any significant differences in MARS-R (both administrations), MATH-S, FIELD, COURSE, and cumulative score. A significant overall F was found for the main effect of class level, $F(6,63) = 2.58$, $p < .027$. However, when univariate follow-ups were performed for each dependent variable, no significant differences were found.

Conclusions

Mathematics ability was once again the most consistently important predictor of achievement in statistics. There are, however, some inconsistencies between Experiment 2 and Experiment 3. In Experiment 2, MATH was the most potent predictor for all groups except the females, while in Experiment 3 MATH-S is the most potent predictor for all groups except the males. There was still, however, no significant differences in achievement for any group, supporting the hypothesis that no one of the variables measured here is singularly essential to success in the course.

In Experiment 2, when anxiety was measured in conjunction with the examinations, it did not change significantly across the semester. In this experiment, however, when anxiety was measured between examination administrations, it did decrease significantly. The amount of variance in the course grade that

they account for, however, remained fairly consistent with anxiety measured at the beginning of the semester having a far lower correlation with course grade than anxiety measured towards the end of the semester.

DISCUSSION

This paper began with six beliefs that we wished to examine. This discussion will now look at each of those beliefs in light of the evidence presented.

Belief 1 suggested that anxiety is debilitating to statistics achievement in the classroom. Anxiety does appear to have a relationship with achievement. The nature of that relationship, however, is unclear. Anxiety about the course at the beginning of the semester appears to have little relationship to the end result in terms of achievement, but anxiety about a particular test does have a strong negative relationship with achievement. These results would seem to indicate that the anxiety is a result of a realistic self-assessment of ability. Whether or not this is the case must wait for an assessment of the specific factors that may be causing test anxiety besides ability so that they may be experimentally manipulated or investigated via a causal approach.

The second belief postulated that undergraduates and graduates approach and react to statistics differently. This belief was not substantiated. No differences were found in mathematics background, attitude, anxiety, or achievement in the course. What

does appear to differ is how the set of variables interact to produce a particular level of achievement. It is at least suggested by these results that deficiencies in any particular area can be compensated for by strengths in another area.

Belief 3 suggested that mathematics ability is important for the successful completion of a statistics course. These results suggest that, while significantly positively related to achievement, it is not overwhelmingly so. The strongest relationship found suggested that only 36% of the variance was due to mathematics ability. This, together with the finding that when background is considered it is only the years since taking mathematics, not the quantity of courses that is important, suggests that only a minimal mathematics background is necessary. This, in turn, suggests that only brief remedial workshops in mathematics may be sufficient to correct a deficiency in this area. Further research exploring the effects of lengthy vs brief remedial workshops is needed.

Belief 4 suggested that there are differences in the factors which are related to achievement in men and women. Similar to the graduates and undergraduates, no differences were found in performance on any of the factors. There were, however, differences in how those factors related to performance. Results presented here were inconsistent as to the pattern of variables,

but it is clear that the variables studied here can interact in various ways to produce the same achievement results.

The belief that attitudes about statistics can influence statistics achievement was also investigated. It was found that, while attitude toward the course, measured at the beginning of the semester, was significantly related to performance, attitude toward the field was, generally, not related to performance. This suggests that a supportive atmosphere can help achievement in the course, regardless of attitude toward the field of statistics. Further research in this area is suggested.

Finally, Belief 6 states that logical reasoning skills are important to statistics achievement. From the evidence presented here, logical reasoning skills do have a substantial relationship with achievement. As with mathematics achievement, however, the relationship is not an overwhelming one. The difference between mathematics skills and logical reasoning skills is that mathematics skills would seem to be easier to remediate. This suggests that where logical reasoning skills are deficient, other abilities must be strongly reinforced, or differential teaching strategies used.

In summary, mathematics ability, logical reasoning ability, attitude toward statistics, and anxiety have been shown to have some relationship with statistics achievement. In addition, even when undergraduates and graduates, and men and women have few

differences in background, attitude, and achievement, the effects of these variables on achievement appear to differ across groups. Further research is needed to clarify the patterns of these differences and to investigate potential ways of maximizing statistical achievement given the variety of cognitive and affective dimensions in the students.

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TABLE 1

Means and Standard Deviations for Experiment 1

Variable	Mean	SD	N
TOLT	6.98	2.49	51
State Anxiety	38.55	11.57	51
Trait Anxiety	35.47	6.82	51
No. of Math Courses	4.45	2.71	51
Yrs Since Taking Math	4.20	1.08	51
First Exam	53.20	8.35	51
Final Exam	51.38	9.15	45

TABLE 2

Pearson Correlation Coefficients for Experiment 1

	1	2	3	4	5	6
1. TOLT	---					
2. State Anx	-.42**	---				
3. Trait Anx	.07	.19	---			
4. No. of Math Courses	.42**	-.22	.19	---		
5. Yrs Since Taking Math	-.30*	.22	-.25	-.57**	---	
6. First Exam	.46**	-.47**	.04	.34*	-.14	---
7. Final Exam	.43**	-.33*	.18	.09	.13	.64**

* $p < .05$ ** $p < .01$

TABLE 3

Stepwise Multiple Regression, Multiple Correlations, and Parsimonious Model Regression Weights for Total Group, First Exam

Step No.	Variable Entered	Mult R	SE Est	df	F	R2	Inc R2	b	t for Inclu
1	State Anx	.47	7.43	49	14.23**	.22	---	-.25	-2.58*
2	TOLT	.55	7.09	48	10.66**	.31	.09	1.06	2.39*
					Constant 55.29				

* $p < .05$ ** $p < .01$

TABLE 4

Stepwise Multiple Regression, Multiple Correlations, and Parsimonious Model Regression Weights for Total Group, Final Exam

Step No.	Variable Entered	Mult R	SE Est	df	F	R2	Inc R2	b	t for Inclu
1	TOLT	.44	8.33	43	10.10**	.19	---	1.92	3.77**
2	Yrs Since Taking Math	.52	8.02	42	7.61**	.27	.08	2.45	2.08*
					Constant			27.56	

* $p < .05$ ** $p < .01$

TABLE 5

Stepwise Multiple Regression, Multiple Correlations, and Parsimonious Model Regression Weights for Graduates, Final Exam

Step No.	Variable Entered	Mult R	SE Est	df	F	R2	Inc R2	b	t for Inclu
1	Trait Anx	.61	7.31	26	15.02**	.37	---	.79	4.11**
2	TOLT	.73	6.36	25	14.64**	.53	.16	1.66	3.07**

Constant 13.77

* $p < .05$ ** $p < .01$

TABLE 6

Means and Standard Deviations for Experiment 2

Variable	Mean	SD	N
MARS-R	63.35	20.05	88
Trait Anxiety	35.17	9.15	88
State Anxiety, First Exam	46.87	13.58	84
First Exam	-.15	1.49	88
State Anxiety, Final Exam	42.49	13.82	74
Final Exam	.19	1.04	81
Cumulative Exam Score	.17	.79	82
Math Achiev.	22.29	9.51	78
Attitude Toward Statistics	103.51	13.40	71

TABLE 7

Pearson Correlation Coefficients for Experiment 2

	1	2	3	4	5	6	7	8
1. MARS-R	---							
2. Trait Anx	.39**	---						
3. State Anx, First Exam	.51**	.22*	---					
4. First Exam	-.35**	-.12	-.32**	---				
5. State Anx, Final Exam	.36**	.13	.54**	-.16	---			
6. Final Exam	.01	.10	-.14	.54**	-.22*	---		
7. Cum Exam Score	-.14	.01	-.17	.79	-.39**	.84**	---	
8. Math Achiev.	-.53**	-.03	-.40**	.41**	-.28*	.28	.37**	---
9. ATS	.06	-.15	.06	.43*	-.19	.09	.14	.32

* $p < .05$ ** $p < .01$

TABLE 8

Means and Standard Deviations for Experiment 3

Variable	Mean	SD	N
MARS-R 1st admin	68.91	18.95	134
MATH	12.96	6.31	138
FIELD	-.05	.99	82
COURSE	-.04	.95	82
MARS-R 2nd admin	64.85	19.03	92
Cumulative Exam Score	-.00	1.90	136

TABLE 9

Pearson Correlation Coefficients for Experiment 3

	1	2	3	4	5
1. MARS-R 1st admin	---				
2. MATH	-.52**	---			
3. FIELD	-.12	.29**	---		
4. COURSE	-.75**	.58**	.39**	---	
5. MARS-R 2nd admin	.63**	-.49**	-.03	-.60**	---
6. Cum Exam Score	-.19*	.43**	.18	.26*	-.32**

* $p < .05$ ** $p < .01$

TABLE 10

Split Plot ANOVA for the Factors Sex,

Class Level, and MARS-R

Source	SS	DF	MS	F
Sex	13.50	1	13.50	.02
Class Level	51.50	1	51.50	.08
S x C	203.93	1	203.93	.33
Error	47406.32	77	615.67	
MARS-R	1046.52	1	1046.52	7.73**
M x S	265.49	1	265.49	1.96
M x C	97.88	1	97.88	.72
M x S x C	53.77	1	53.77	.40
Error	10420.33	77	135.33	

** $p < .01$